

Attachment #1 to  
OXC-1019

### IONIZATION PROGRAM

In December 1959 a program was initiated to investigate the use of an ionized gas in the jet of an afterburning turbojet engine. A J57 engine was set up on a sea level test stand and attenuations were measured both with and without ionizing materials added. The materials used were salts of sodium, potassium, and cesium dissolved in alcohol.

The results obtained in the sea level tests indicated that satisfactory levels of attenuation could be achieved but attempts to analytically predict metal flows at altitude resulted in flow rates that were of such a wide range of values as to be completely unbelievable. It was suspected that this wide range of predicted metal flows was due to:

1. An effective temperature function which resulted in lower ionization potentials than the known potentials of the material being tested.
2. Lack of appreciation for the effect of density (collision frequency).

Accordingly, a J57 engine was set up in the Willgoos Laboratory at East Hartford. Object of this test was to provide an additional step in the density temperature spectrum to improve our ability to predict metal flows at the cruise conditions.

Since the Willgoos Lab could not physically produce the temperatures and densities which would be experienced at maximum high altitude cruise, a scale test was set up in the UAC Laboratory using a JT-8 burner and jet nozzle sized to produce the densities and temperatures which will be experienced at altitude cruise conditions.

While these tests were being set up, it was decided by all parties concerned that in addition to attenuation, phase shift should be measured in order to get a better feel for plasma frequency, collision frequency and, by analysis effective temperatures.

The Willgoos Lab tests have been completed and some of the low temperature tests at the UAC Lab have been completed.

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Approved For Release 2001/09/03 : CIA-RDP81B00879R001000030068-8

Following is a listing of:

1. Objectives
2. Results of the data now in hand in terms of things we think we know.
3. Questions not resolved.
4. Future program to be completed.

It should be noted that these comments are concerned only with the problem directly at hand, that of providing an ionized plug in the tail pipe of a jet engine.

Some of the things that have been learned can be applied to the general field of plasma physics but we do not propose that under this program these should be followed beyond the point necessary to accomplish the present task.

Some side effects which may be important to other means of detection have been noted. These are mentioned as a matter of record and are being assessed by the appropriate group in the program.

As a part of this review, we have not entered into any discussion of the hardware involved on either the engine or the aircraft.

Signed by:



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## 1. Initial Objectives

1. To determine if ionisation of sufficient levels to conceal the engine outlet could be produced in a jet engine after-burner exhaust.
2. To determine the best material for producing this ionisation.
3. To produce this ionisation over the full range of after-burning at altitude.
4. To acquire sufficient data to permit prediction of required metal flows vs. altitude and temperature.
5. To determine the amount of ionising material required to be carried per engine on an aircraft performing a specific mission.

## 2. Known

1. 20%/hr. cesium in a 1 meter dia. flame will produce  $f_0 = 1000$  or more, at the exit plane of a J57 engine. When operating at a density approximately equivalent to  $11 \times 10^{-5}$  slugs/cu. ft. and at calculated static temperatures of  $2000^\circ\text{F}$ .
2. 2.0%/hr. cesium in a  $10''$  dia. flame will produce  $f_0 = 1000$  or more at the exit plane when operating at a density approximately equivalent to  $2.5 \times 10^{-5}$  slugs/cu. ft. and at a calculated static temperature of  $1400^\circ\text{R}$ . (This was accomplished in the UAC Lab).
3. Of the materials tested, cesium appears to have significant advantages over potassium and sodium in terms of providing the desired ionisation levels, however, there may be some other means, such as availability, handling, etc., which may make potassium a desirable material to use. Therefore, potassium will continue to be considered.
4. If calculated static temperatures are used, and equilibrium conditions are assumed, the use of the Saha equation predicts ionisation levels which are much lower than those observed.

Reasons for this variance are as follows:

- a. Equilibrium probably does not exist; therefore, static temperature is not a true measure of the probability of ionization.
- b. The electron temperature is suspected to be higher than the static temperature by a factor of several hundred per cent.

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2. 5. A high confidence level can be assigned to the measurements made because collision frequencies agree within reasonable limits with values of collision frequency determined by other methods and other experimenters.
6. Based on the data achieved to date and applying corrections for the difference between the test jets and the J58 jet, the following flow rates and total metal weights based on pure osmium metal would apply:

	<u>Max A/B</u>	<u>Min A/B</u>	<u>Tot. 2 Hr Mission Req.</u>
$f_0 = 100$	1.8#/hr	7 #/hr	6.5#/engine
$f_0 = 500$	7.2	36 #	30#
$f_0 = 1000$	14	70 #	60#

This is based on the use of the most conservative correction factors applied to Willgoos Lab data. Therefore, using a conservative estimate of temperature gradient, the maximum pure metal required can be as high as 60# and using the most optimistic estimate of temperature gradient, as low as 6.5# per engine per mission.

### 3. Questionable Areas

1. What is the rate of effective temperature deterioration in the jet plume?
2. What is the ultimate goal of  $f_0$  at the exit of the tail pipe? This is a function of deterioration rate noted above and the basic goal of  $f_0 = 100$  at 1 dia. downstream of the exit.
3. What is proper carrier for ionization material and what physical hardware is required in the airframe and engine?

### 4. Future Program

1. Complete tests currently planned for UAC Research Laboratory which are directed at more clearly defining the effects of additives at the exit plume under the other engine operating conditions.
2. Examine spectrographically the emission spectrum of the flame with and without additives. Conclusions as to the electron temperature, and the proper distribution function with which to describe the atomic state can be drawn from these measurements.

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4. 3. Investigate the possibility of setting up a test by minor modification to UAC equipment to investigate effects of radiation and change of state, as a function of the distance from the exit plane.
4. Make a spectrographic examination of jet plumes of J58 and J57 engines at sea level.